ASSESSMENT OF ENVIRONMENTAL TOBACCO SMOKE AND RESPIRABLE SUSPENDED PARTICLE EXPOSURES FOR NONSMOKERS IN KUALA LUMPUR USING PERSONAL MONITORING

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The study was centered in Kuala Lumpur, Malaysia, and comprised housewives in one group, primarily for assessing exposures in the home, and office workers in a second group to assess the contribution of the workplace to overall exposure. Two hundred and forty one randomly selected nonsmoking subjects collected air samples near to their breathing zone by wearing one (housewives) or two (office workers) personal monitors for 24h. Samples collected were analyzed for respirable suspended particles (RSP), nicotine, 3-ethenylpyridine and environmental tobacco smoke (ETS) particles using ultraviolet absorbance (UVPM), fluorescence (FPM) and solanesol (SolPM) measurements. Saliva cotinine analyses were also undertaken to confirm the nonsmoking status of the subjects and a misclassification rate of between 2.8 and 3.2% was estimated. The highest exposures to ETS particles and nicotine were found for office workers living in smoking homes, irrespective of the workplace smoking status. Based upon median levels, these subjects had potential inhaled quantities (PIQ) of up to 1.3 cigarette equivalents per year (CE/y). All other groups investigated in this study had median PIQs of considerably less than 1 CE/y. Based upon 90th percentile levels, the most highly exposed subjects in this study would potentially inhale between 1.9 and 4.6 CE/y. Overall, these were the lowest PIQs reported to date by these authors.

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2. Abbreviations: ANOVA, analysis of variance; CE, cigarette equivalent; CE/y, cigarette equivalent per year; CIAR, Center for Indoor Air Research; 3-EP, 3-ethenylpyridine; ETS, environmental tobacco smoke; FPM, fluorescing particulate matter; LOQ, limit of quantification; PIQ; potential inhaled quantity; RSP, respirable suspended particles; SolPM, solanesol related particulate matter; SRM, Survey Research Malaysia; TWA, time weighted average; US, United States; UVPM, ultraviolet light absorbing particulate matter.

3. Key words: environmental tobacco smoke; nicotine; personal exposure; respirable suspended particles.

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INTRODUCTION

Kuala Lumpur was the second South East Asian city studied by these authors on air quality, following on from Hong Kong (Phillips et al., 1998f). These South East Asian studies were conducted using an identical protocol to the studies already completed in Europe, namely Stockholm, Barcelona, Turin, Paris, Bremen, Lisbon, Basel and Prague (Phillips et al, 1996, 1997a, 1997b, 1998a-e). Kuala Lumpur, the capital city of Malaysia, is situated in the Klang Valley and has a population of approximately 1.7 million, and is currently one of the most rapidly developing industrial cities in the world. Air quality is of particular concern in this city where the byproducts of industrial expansion are impacting upon the environment, vehicular pollution being a major source with over four times the number of cars today compared with 10 years ago. The Malaysian Department of the Environment in conjunction with the Malaysian Meteorological Services issued a report in 1994 indicating the deterioration of air quality in the country. Regulations are usually adopted to control these sources of ambient pollution but more serious in 1997 was the atmospheric pollution of the Malaysian peninsular attributable to combustion products emanating from forest fires in Indonesia. In these situations the quality of indoor air is of heightened importance if the population of cities like Kuala Lumpur are to get any respite from uncontrollable conditions prevailing outside.

Personal air monitoring was chosen for this study in preference to static or ambient measurements in order to more accurately represent personal exposures to selected pollutants. The study involved subjects monitoring the air close to their breathing zone over 24 h periods in Kuala Lumpur during March and April 1996. Legislation controlling smoking in the workplace has been introduced in the United States (US) and is the subject of much debate in Europe. To date very few studies have been conducted either in Europe or in South East Asia. This study is one of a series which set out to establish respirable suspended particle (RSP) and environmental tobacco smoke (ETS) levels both at work and in all other locations, including the home. Volatile organic compounds were also monitored inside and outside the homes of more than 20 participants and preliminary data have been reported recently (Phillips et al., 1997c). ETS particles were estimated using ultraviolet absorbing particulate matter (UVPM), fluorescing particulate matter (FPM) and solanesol related particulate matter (SolPM). Vapor phase ETS exposures were also assessed by simultaneous measurement of nicotine and 3-ethenylpyridine (3-EP) concentrations. In order to evaluate exposures to ETS and RSP, households and workplaces were classified as smoking or nonsmoking. Subjects provided saliva samples for cotinine analysis and also self-reported activities using diaries and questionnaires. Similar methodologies have been used in other recent studies (Sterling et al., 1996; Heavner et al., 1996; Jenkins et al., 1996; Baek et al., 1997).

The study set out to assess the exposure of housewives and office workers to RSP and ETS particles by obtaining accurate measurements of air concentrations. The information collated here should provide some meaningful data to allow informed and objective debate on issues related to passive smoking and exposures to RSP overall. The main objectives of this study were:

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(1) To recruit random subjects, who were representative of the population of Kuala Lumpur, into six separate lifestyle "Cells".
(2) To determine the range and degree of personal exposure of these Cells of selected subjects to RSP and ETS constituents by means of personal air sampling over a 24-h period.
(3) To assess the contribution of the workplace to overall ETS and RSP exposure.

METHODS

Recruitment of Subjects

Recruitment was performed by Survey Research Malaysia (SRM) Sdn Bhd, a leading Asian marketing company, who possessed the most complete personal databases in the region. A random sample population was selected from these databases to be compliant with the following criteria:

(1) All subjects to be nonsmokers living within 15 km of Kuala Lumpur city centre.
(2) Equal proportions from three age groups 20–34, 35–49, and 50–64.
(3) Subjects' lifestyles to be representative of the population within 15 km of the city centre.
(4) Subjects to be distributed between six "Cells" as indicated in Table 1, Cells 3–6 being targeted at office workers.

Addresses were selected at random from the sample population and potential subjects were screened in person at their home to confirm eligibility for participation in the study. Suitable volunteers were given an appointment to attend an information/training session organized at the offices of SRM in Petaling Jaya, Kuala Lumpur.

In order to assign subjects into Cells, as depicted in Table 1, the same procedures were used as in previous studies by these authors. A subject's household was classified as "smoking" if a smoker of cigarettes, pipes or cigars was resident and also normally smoked within communal areas of the household. Office workers were questioned regarding the number of co-workers who smoked any tobacco products at various distances from their personal workspace. The smoking status of a workplace was defined by the absence/presence of smoking co-workers within 30 meters of the subject's workstation, this was the maximum distance specified and was intended to characterize the majority of office areas. At distances beyond 30 meters any tobacco smoke reaching the subject would be expected to have been diluted to levels below the LOQ in this study. There was the possibility of smoking occurring in a nonsmoking office and conversely a lack of smoking taking place in a smoking office. These definitions were chosen to best represent 'real world' situations and for consistency across the different cities under study, since the attitudes of their residents vary considerably from country to country. The regulations governing air quality in the workplace were also different in each country at the time the study was undertaken.

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TABLE 1. Cell Categorization by Home and Workplace Status

Cell	Study type	Smoking status		Planned number
		Household	Workplace	
1	Single Monitor	Smoking	-	55
2	Single Monitor	Nonsmoking	-	40
3	Dual Monitor	Smoking	Smoking	45
4	Dual Monitor	Smoking	Nonsmoking	30
5	Dual Monitor	Nonsmoking	Smoking	40
6	Dual Monitor	Nonsmoking	Nonsmoking	30

The Monitoring Session

Subjects were required to wear a personal monitor, designed to collect particulate and vapor phase components present in the air close to the subject's breathing zone (Ogden et al., 1996). RSP and ETS particles were collected onto a Fluoropore membrane filter, nicotine and 3-EP were adsorbed onto XAD-4 resin beads. The personal monitoring methodology has been described in detail elsewhere (Phillips et al., 1996) and consisted briefly of the following:

Initial Visit to the Study Centre: On arrival subjects were shown an instructional video, in the English language, or dubbed into either Bahasa Malay or Cantonese, which explained the objectives of the air quality survey. They were also given further instructions regarding use of the equipment and how to complete the documentation by locally recruited interpreters. Subjects were issued with questionnaires and diaries, in the appropriate language, for recording exposures and observations over the 24 h collection periods. Subjects were supervised during completion of the "first visit" questionnaire. In order to avoid misinterpretation and possible errors in translation, all questionnaires and diaries were designed for either numeric or tick-box answers. Nonworking subjects recruited for participation in Cells 1 and 2 were provided with a single personal monitor for use over the collection period (single monitor study). Working subjects recruited for participation in Cells 3 to 6 were provided with two personal monitors for use over the same period (dual monitor study). All subjects were required to provide a saliva sample prior to the monitoring period (pre-sample).

Final Visit to the Study Centre: Following completion of the 24 h monitoring period, subjects returned their personal monitors and associated documentation to the study centre. Subjects also provided a second saliva sample (post-sample), completed a "last visit" questionnaire and received a payment as compensation for their inconvenience.

ANALYTICAL PROCEDURES

All analytical procedures were validated and have been fully described previously by these authors (Phillips et al., 1996). In this study the following analytes were determined:

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(1) *RSP* using a gravimetric procedure (Ogden et al., 1990).
(2) *Saliva cotinine* — using a radioimmunoassay procedure (Van Vunakis et al., 1987, Davis and Stiles, 1993).
(3) *Nicotine and 3-EP* — using a capillary gas chromatography procedure with nitrogen specific detection (Ogden et al., 1989).
(4) *Estimation of ETS particles (3 procedures)* — using high performance liquid chromatography (HPLC) procedures to determine the ultraviolet absorbance (UVPM), fluorescence (FPM) or solanesol content (SolPM) of methanolic filter extracts (Ogden et al., 1990, Phillips et al., 1996). The factors used in this study to convert instrument responses into an equivalent concentration of ETS particles were 42 (SolPM), 44 (FPM) and 8.1 (UVPM) as determined by Nelson et al. (1997).

The analytical limits of quantification (LOQ) for these analyses are presented in Table 2, together with the proportion of data below the LOQ. In order to calculate summary statistics, any data below the analytical LOQ were assigned a value of 1/2 LOQ prior to the calculation of exposure concentration using the appropriate air sampling volume. The LOQs expressed as air concentrations in Table 2 are therefore only an approximation as they varied for each sample dependent upon the sampling pump flow rate and monitoring time.

TABLE 2. Limits of Quantification (LOQ) for the Analytical Methods

Measurement *	Analytical LOQ	LOQ expressed as an air concentration according to sampling time ($\mu g\ m^{-3}$) **			Proportion of data below the LOQ
		24 h	14.7 h *1*	9.10 h *2*	
RSP	15.8 µg/filter	8.2	13.4	21.7	3%
UVPM	1.28 µg/filter	0.49	0.80	1.3	1%
FPM	0.30 µg/filter	0.11	0.19	0.30	2%
SolPM	0.84 µg/filter	0.25	0.41	0.67	66%
Nicotine	0.1 µg/tube	0.09	0.14	0.23	63%
3-Ethenylpyridine	0.1 µg/tube	0.09	0.14	0.23	76%
Saliva cotinine	1.0 ng mL^{-1}	--	--	--	72%

* RSP: Respirable suspended particles.
UVPM: Environmental tobacco smoke (ETS) particles estimated by ultraviolet absorption.
FPM: ETS particles estimated by fluorescence.
SolPM: ETS particles estimated by solanesol content.

** A flow rate of 1.72 L min^{-1} through the Fluoropore filter was assumed in the LOQ calculation for RSP, UVPM, FPM and SolPM. The LOQ calculation for nicotine and 3-ethenylpyridine assumed a flow rate of 0.8 L min^{-1} through the XAD-4 tube.

1 Mean time spent outside the workplace for working subjects in Kuala Lumpur.

2 Mean time spent at work for working subjects in Kuala Lumpur.

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SUBJECT SELECTION

Of the 250 subjects that were initially recruited for the study, one was excluded after having admitted to being a smoker during the initial visit to the study centre. A further subject was excluded as their nonsmoking status could not be confirmed due to the absence of saliva cotinine data and 7 subjects were excluded because their saliva cotinine levels were above the selected threshold (25 ng mL^{-1}) for nonsmokers.

The age and sex distributions of the remaining 241 subjects who successfully completed the study are presented in Table 3. The sex distribution was very close to the planned 50% per sex for office workers in the dual monitor study (45% male, 55% female). The age distribution for office workers showed a considerable variation from the planned 33% for each age group, with 74% of the recruits falling into the youngest (20–34 years) age group, reflecting the fact that approximately 70% of Kuala Lumpur's urban population is aged below 30 years. Housewives in the single monitor study showed a more even age range distribution with approximately 50% of the recruits being aged between 35 and 49 years. These variations in the age range distributions from those planned are possibly a reflection of the demographics for office workers and housewives in Kuala Lumpur. The dual monitor study participants were also questioned about their occupation on the first visit questionnaire. Subjects were restricted to a choice of 12 occupations from which to select and provide their answers as summarized in Table 4. Further information regarding occupations, particularly for the 22% of office workers describing themselves as "other", was not available.

TABLE 3. Age and Sex Distribution for Study Subjects

Subject group	Sex		Age range			Overall total
	Males	Females	20 - 34	35 - 49	50 - 64	
Cell 1		42	11	22	9	42
Cell 2		51	12	27	12	51
Cell 3	17	13	24	6		30
Cell 4	10	19	24	4	1	29
Cell 5	15	30	31	13	1	45
Cell 6	24	20	31	11	2	44
Single monitor total		93	23	49	21	93
Dual monitor total	66	82	110	34	4	148
Overall total	66	175	133	83	25	241

Cell 1 : smoking household
Cell 2 : nonsmoking household
Cell 3 : smoking household / smoking workplace
Cell 4 : smoking household / nonsmoking workplace
Cell 5 : nonsmoking household / smoking workplace
Cell 6 : nonsmoking household / nonsmoking workplace

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TABLE 4. Occupations of Recruited Working Subjects

Occupation	Number of responses
Administrative/Secretarial	52
Building/Construction	0
Education	7
Engineering	7
Government Agency (Civil Service)	13
Legal/Financial (eg Solicitor, Banker)	20
Hotel/Restaurant/Leisure industry	3
Medical (eg doctor, nurse)	2
Wholesale/Retail (eg Shop assistant)	3
Science/Computing	6
Supply Industry (eg electricity, gas, water, telephones)	0
Other	33
Transportation/Haulage (eg lorry, taxi, bus driver)	0
Total	146

During recruitment it was apparent that smoking was not very widespread in indoor environments and difficulties were encountered in recruiting subjects from smoking households and, in particular, smoking workplaces. Some modern office buildings had smoking restrictions and therefore recruitment of the planned number of subjects into certain Cells proved to be unachievable.

RESULTS AND DISCUSSION

Weather Conditions

This study involving more than 240 local inhabitants, commenced on March 18th, 1996 and was completed on April 6th, 1996. The local Meteorological Service Department reported in a local daily newspaper that 154.6 mm rain fell in 6 h in the Klang Valley on 21st March 1996. This was the highest rainfall figure in March for 30 years and since records began locally. Correlation of our findings with high rainfall, relative humidity or temperature was not undertaken due to the short time period, and limited number of subjects in the study. It is likely that the high rainfall would have reduced levels of both particulate and vapor phase compounds in outdoor air, potentially reducing indoor air concentrations.

Smoking Status and Misclassification

Saliva cotinine levels were determined in order to verify that recruited subjects had correctly reported themselves as nonsmokers. Various threshold levels, above which subjects would be classified as smokers, have been suggested and include 10 ng mL^{-1} (Etzel, 1990), 15 ng mL^{-1} (McNeill et al., 1987), 30 ng mL^{-1} (Lee, 1987) and more recently 100 ng mL^{-1} (Sterling et al., 1996). In this study 25 ng mL^{-1} (maximum of pre- and post-levels) was chosen as a suitable cut-off level, as used and described previously in a British study (Phillips et al., 1994). Using this threshold, 7 subjects with levels between 27.1 and 449 ng mL^{-1} were assumed to be smokers and were excluded from the study. One subject was excluded from the study as their nonsmoking status could not be confirmed due to the absence of saliva cotinine data. A further subject was

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excluded after admitting to being a smoker on the first visit questionnaire; however the measured saliva cotinine levels (0.5 and 1.6 ng mL^{-1}) were not indicative of a regular smoker. This possibly suggests that the subject abstained from smoking for several days before the study started, was a "light" smoker or non-inhaler ("mouth-puffer"), had misreported their smoking status, or inefficiently metabolized nicotine to cotinine. This latter phenomenon has received some recent attention in the literature and has been summarized by Ogden et al. (1997).

In this study, subjects were required to confirm they had been nonsmokers for more than six months and no attempt was made to differentiate between "non" and "never" smokers. Various criteria can be used to assess the rate at which recruited subjects misreport their smoking status, including responses to questionnaires. Depending upon the criteria used, the rate at which subjects misclassified their smoking status in this study ranged between 2.8% (7 from 248) and 3.2% (8 from 249). These misclassification rates were approximately 50% lower than the overall average range determined for the European cities (5.0–7.0%) and for Hong Kong (5.4–6.3%) by these authors.

Etzel's review (1990) of the use of saliva cotinine for this purpose suggests that subjects with cotinine levels between 10 and 100 ng mL^{-1} may be classified as infrequent smokers. It is interesting to note that, had 10 ng mL^{-1} had been selected as the cut-off level for discriminating between smokers and nonsmokers in Kuala Lumpur, no further subjects would have been rejected. Ogden et al. (1997), in a nationally representative study of married females in the US, could have rejected 64 out of 699 (9.2%) self-reported nonsmokers using a threshold of 10 ng mL^{-1} or 33 out of 699 (4.7%) using a threshold of 106 ng mL^{-1}. An exclusion rate of 4.2%, using a 15 ng mL^{-1} saliva discrimination level, was found on a recent personal air monitoring study (Jenkins et al., 1996) for 1564 subjects in the US.

Comparison of "Markers" for Estimating ETS Concentrations

Table 5 lists the correlation and best fit line coefficients between various analytes measured in this study, after removal of data pairs where either analyte was below the LOQ. Cumulative frequency distributions for all analytes, calculated as 24-h time weighted average (TWA) air concentrations, are presented in Figure 1. Examination of Table 5 shows an excellent correlation between UVPM and FPM measurements, although this is not surprising since the majority of determined FPM particles will also be detected by UVPM methodology. Poor correlations for ETS particles were found between SolPM estimates and those determined using FPM (R^2 = 0.38) and UVPM (R^2 = 0.26) methods, albeit slightly better for FPM. The gradients determined from these correlations show that both UVPM and FPM estimates of ETS particles were considerably higher than SolPM, indicating a likely contribution to UVPM and FPM levels from non-ETS related sources.

A moderate correlation was evident between the vapor phase analytes nicotine and 3-EP (R^2 = 0.59), and a poor correlation was found between 3-EP and SolPM estimates (R^2 = 0.37). It is interesting to note that 3-EP measurements correlated much better with particulate phase estimates than nicotine, possibly confirming the suitability of 3-EP as an indicator for ETS particulate phase behavior (Nelson et al., 1992). An analytical methodology with a considerably increased sensitivity would be required to investigate further the behavior of 3-EP at the low levels encountered in this study.

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TABLE 5. Correlation Coefficients for ETS 'Markers' Using Only Data Greater than the LOQ

"Y" data v	"X" data	n*	R-squared	Gradient	Intercept
FPM	UVPM	374	0.95	0.77	-0.99
SolPM	UVPM	130	0.26	0.23	1.5
SolPM	FPM	130	0.38	0.39	0.73
3-EP	Nicotine	82	0.59	0.19	0.33
FPM	Nicotine	138	0.01	0.43	15
SolPM	Nicotine	98	0.01	0.16	7.2
UVPM	Nicotine	139	0.01	0.59	22
SolPM	3-EP	70	0.38	16	-0.25
FPM	3-EP	89	0.40	27	1.0
Post-cotinine	Nicotine**	30	0.16	0.25	2.0
Post-cotinine	SolPM**	24	0.41	0.07	1.7
Post-cotinine	FPM**	55	0.11	0.02	1.7

* This refers to the number of 'data pairs' analysed, ie data from an individual monitor. It is not equivalent to the number of subjects as 2 monitors were worn by subjects in Cells 3 to 6.

** Time weighted average concentrations used for working subjects (Cells 3 to 6) having results from both the "workplace" and "outside of the workplace" monitors greater than the LOQ.

Table 5 also shows poor correlations for post-cotinine concentrations with both vapor and particulate phase ETS measurements ($R^2 < 0.41$). These poor correlations may be due to the large proportion of results being close to or below the LOQ, where acceptable assay reliability is at a minimum. These results reinforce our previous conclusions that cotinine measurements, using the current LOQ, are not a reliable marker for individual ETS exposures.

Concentrations of ETS Constituents to which Kuala Lumpur Subjects were Exposed

In this publication, median values have been primarily used for reporting RSP and ETS marker concentrations since the data generated were highly skewed, arithmetic and geometric means have also been reported to allow easy comparison with data from other authors. In addition, 10th and 90th percentile values have been reported as an indication of the range and distribution within each data set. ETS particle concentrations and comparisons between subject groups and Cells have been based upon SolPM determinations, although FPM values have been quoted alongside for comparison. It has been suggested previously (Ogden et al., 1990) that SolPM, and to some extent FPM, methods are more specific to ETS particles than the use of UVPM methods which will be sensitive to other combustion sources. ETS particle concentrations based upon fluorescence measurements were considered to have provided an overestimate of ETS particle exposures.

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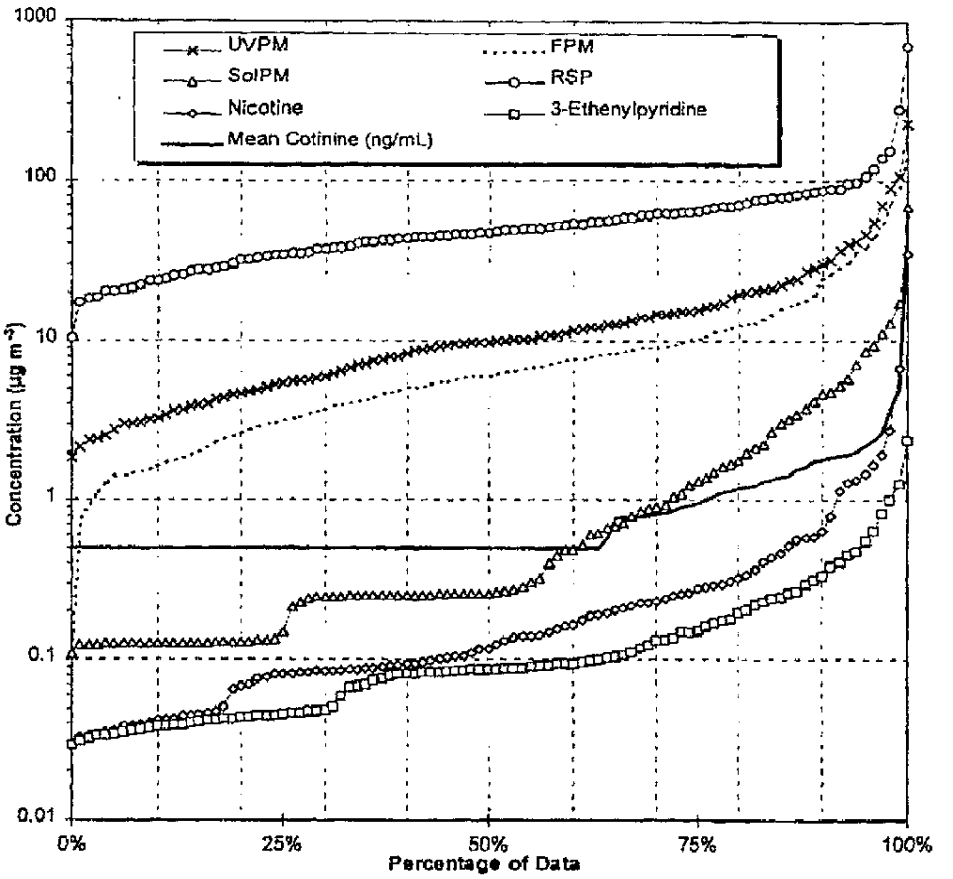

FIGURE 1. Cumulative frequency distributions for 24-h TWA concentrations of all ETS 'markers' found in Kuala Lumpur. RSP: respirable suspended particles, UVPM: ETS particles estimated by UV absorbance, FPM: ETS particles estimated by fluorescence, SolPM: ETS particles estimated from solanesol content.

Particulate and vapor phase components measured for housewives were compared, by Cell, with calculated TWA concentrations for individual workers. These calculations were based on measured concentrations and the operational time over which the monitors were used inside and outside the workplace. These data are summarized in Tables 6 and 7, with corresponding cumulative frequency distributions for ETS particles and nicotine shown in Figures 2 and 3. The significance of any concentration differences between Cells was examined using the Wilcoxon rank sum test. Prior to the application of this nonparametric test, Kruskal-Wallis nonparametric analysis of variance (ANOVA) was applied to the data in order to detect if there was an overall difference

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between the Cells. For RSP the overall Kruskal-Wallis analysis proved nonsignificant ($p > 0.05$) and the Wilcoxon rank sum test was not performed as there would have been the possibility of false positives. For all the other analytes investigated, the Kruskal-Wallis ANOVA provided evidence of a significant overall difference between Cells and subsequent pairwise comparisons of Cells were performed using the Wilcoxon rank sum test.

Median 24-h TWA RSP concentrations found in this study varied between 43 and 52 μg m^{-3}, with no significant differences ($p > 0.05$) apparent between any of the Cells investigated. These levels were near identical to those determined by these authors in Hong Kong, but were up to three times higher than those found in the recent 16 City US study (Jenkins et al., 1996).

The highest median levels of ETS particles (SolPM) were determined for subjects living in smoking households and working in smoking workplaces (Cell 3, 1.5 μg m^{-3}) and for subjects living in smoking households and working in nonsmoking workplaces (Cell 4, 1.6 μg m^{-3}), these concentrations representing approximately 3% of measured RSP. The levels determined for Cell 3 were not significantly different ($p > 0.05$) from those for Cell 4 but were significantly higher (p 0.01) than all other Cells. In all previous cities studied by these authors, Cell 3 has proved to have the highest levels of ETS particles, with medians in Europe varying from 3.0 μg m^{-3} in Stockholm to 35 μg m^{-3} in Barcelona and a median level of 2.6 μg m^{-3} reported for Hong Kong. The median concentration reported here was the lowest found to date by these authors and was also approximately 60% lower than the equivalent Cell in the recent 16 City US study (Jenkins et al., 1996). Housewives, irrespective of the smoking status of their household (Cells 1 and 2), and workers living in nonsmoking households (Cells 5 and 6) were exposed to the lowest levels of ETS particles (SolPM) in this study, all median values falling below their respective LOQs.

The highest median nicotine concentration (0.30 μg m^{-3}) was again found for Cell 3 with measured levels being significantly higher (p 0.05) than all other Cells except Cell 4. The lowest levels were measured for housewives living with nonsmokers (0.05 μg m^{-3}, Cell 2), although median levels for Cells 5 and 6 were also below the limit of quantification. Median nicotine levels were above the LOQ for Cells1, 3 and 4, where subjects were living in smoking homes. This would suggest that in Kuala Lumpur the smoking status of the household was a significant factor in overall ETS exposure.

For 3-EP, there was a larger percentage of data below the LOQ than for nicotine with all median levels reported being at or below the LOQ, suggesting the need for further work by these authors to improve the analytical LOQ for this analyte. In this instance, any significance of differences revealed by Wilcoxon rank sum test results for 3-EP data were not meaningful since most would be attributable to differences in LOQs as a result of different collection intervals. Examination of 90th percentile levels for 3-EP shows a similar trend to nicotine with the higher levels associated with smoking home environments.

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TABLE 6. 24-h TWA Particle Concentrations for all Subjects by Cell

Analyte	Subject group	Number of subjects	10th percentile	90th percentile	Arithmetic mean	Geometric mean	*Median*
	Cell 1	40	28	89	83	58	*52*
	Cell 2	51	21	89	53	46	*48*
RSP	Cell 3	29	22	87	51	45	*50*
($\mu g\ m^{-3}$)	Cell 4	28	26	77	54	50	*52*
	Cell 5	43	26	95	54	47	*43*
	Cell 6	44	25	79	51	43	*43*
	Cell 1	40	0.13	3.7	1.5	0.37	*0.13*
	Cell 2	50	0.12	0.69	1.8	0.21	*0.13*
SolPM	Cell 3	29	0.25	6.5	4.3	1.6	*1.5*
($\mu g\ m^{-3}$)	Cell 4	28	0.25	7.9	2.8	1.2	*1.6*
	Cell 5	44	0.25	2.9	1.2	0.57	*0.26*
	Cell 6	44	0.25	2.9	1.2	0.52	*0.27*
	Cell 1	40	2.4	38	19	9.5	*8.6*
	Cell 2	50	1.8	29	14	6.7	*5.7*
FPM	Cell 3	29	1.6	17	8.9	6.3	*7.7*
($\mu g\ m^{-3}$)	Cell 4	28	2.0	17	9.3	7.2	*8.7*
	Cell 5	42	1.5	12	6.2	4.4	*5.1*
	Cell 6	44	1.4	14	9.1	4.6	*4.0*
	Cell 1	39	4.9	44	26	15	*14*
	Cell 2	50	4.3	33	19	11	*10*
UVPM	Cell 3	29	3.1	22	13	9.7	*11*
($\mu g\ m^{-3}$)	Cell 4	28	3.7	22	13	11	*11*
	Cell 5	43	3.1	20	11	7.9	*7.3*
	Cell 6	44	3.3	26	13	7.9	*7.1*

Cell 1 : smoking household
Cell 2 : nonsmoking household
Cell 3 : smoking household / smoking workplace
Cell 4 : smoking household / nonsmoking workplace
Cell 5 : nonsmoking household / smoking workplace
Cell 6 : nonsmoking household / nonsmoking workplace

Time weighted average (TWA) exposure concentrations, determined for each subject from measured levels both inside and outside the workplace, were used to calculate the above statistical parameters for Cells 3 to 6

Saliva Cotinine

Saliva cotinine concentrations, expressed as an average of pre- and post-monitoring levels, are reported by Cell in Table 7. The highest median concentrations recorded were for office workers living and working with smokers (Cell 3, 0.85 ng mL^{-1}), and living with smokers but working with nonsmokers (Cell 4, 1.1 ng mL^{-1}), with no significant difference ($p > 0.05$) between the two Cells. The levels found in these Cells were significantly higher (p 0.05) than all other Cells with the exception of Cell 1 (housewives living in smoking households), suggesting that living with smokers is the major contributor to the overall ETS exposure of working subjects.

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Source: https://www.industrydocuments.ucsf.edu/docs/gshj0001

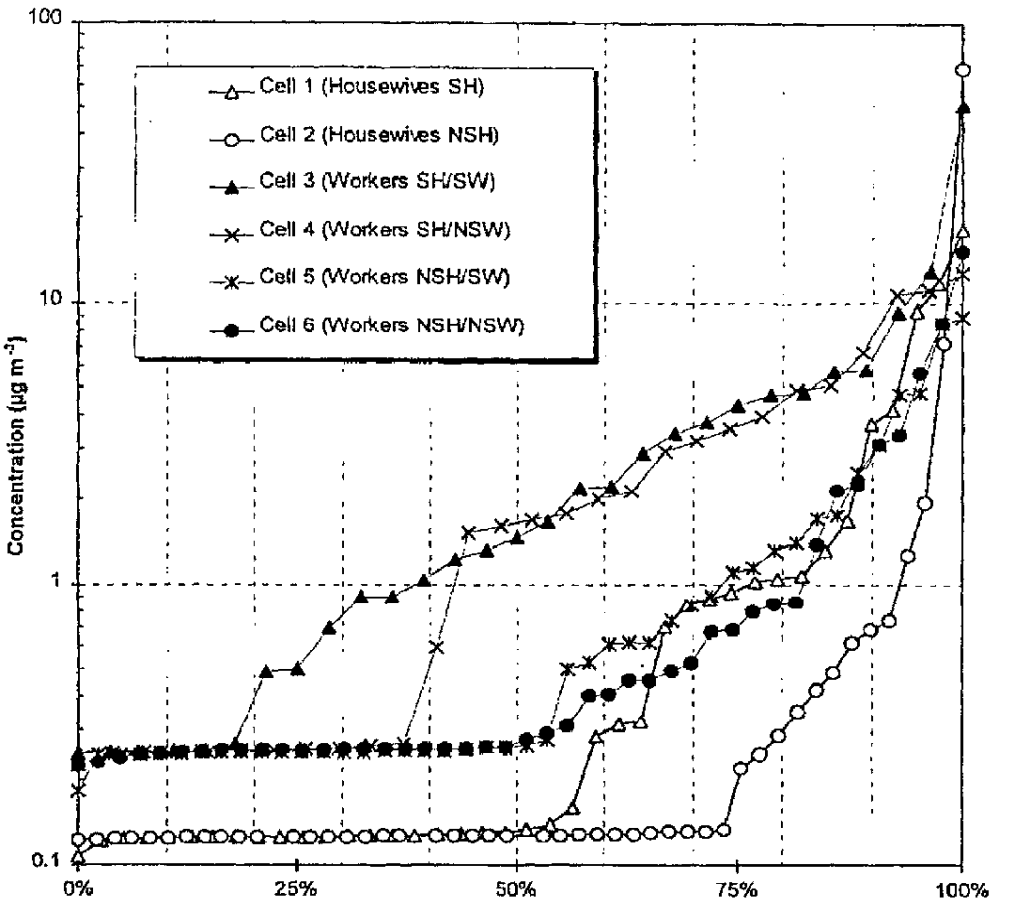

FIGURE 2. Cumulative frequency distributions for 24-h TWA concentrations of ETS particles (SolPM) found in Kuala Lumpur by cell. SH: smoking household, NSH: nonsmoking household, SW: smoking workplace, NSW: nonsmoking workplace.

It was not intended that cotinine should be used as a quantitative marker for ETS exposure in this study and a large majority of the levels found were close to, or below, the LOQ (1.0 ng mL^{-1}). However, the median cotinine levels were consistent with the levels of ETS particles and nicotine which indicates a potential use for saliva cotinine as a marker of ETS exposure in a study population rather than as an individual marker. To improve matters, a method with a greatly improved LOQ would be required, to provide for example, statistical significance between groups of subjects with low levels of exposure (e.g., Cell 5 and Cell 6). Cotinine measurements used for ETS exposure estimates inherit the inadequacies of nicotine behavior and a host of other uncertainties including dietary influences, metabolic differences and the absence of a detailed analytical method in the public domain adequate to quantify levels below 0.1 ng mL^{-1} in body fluids.

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Source: https://www.industrydocuments.ucsf.edu/docs/gshj0001

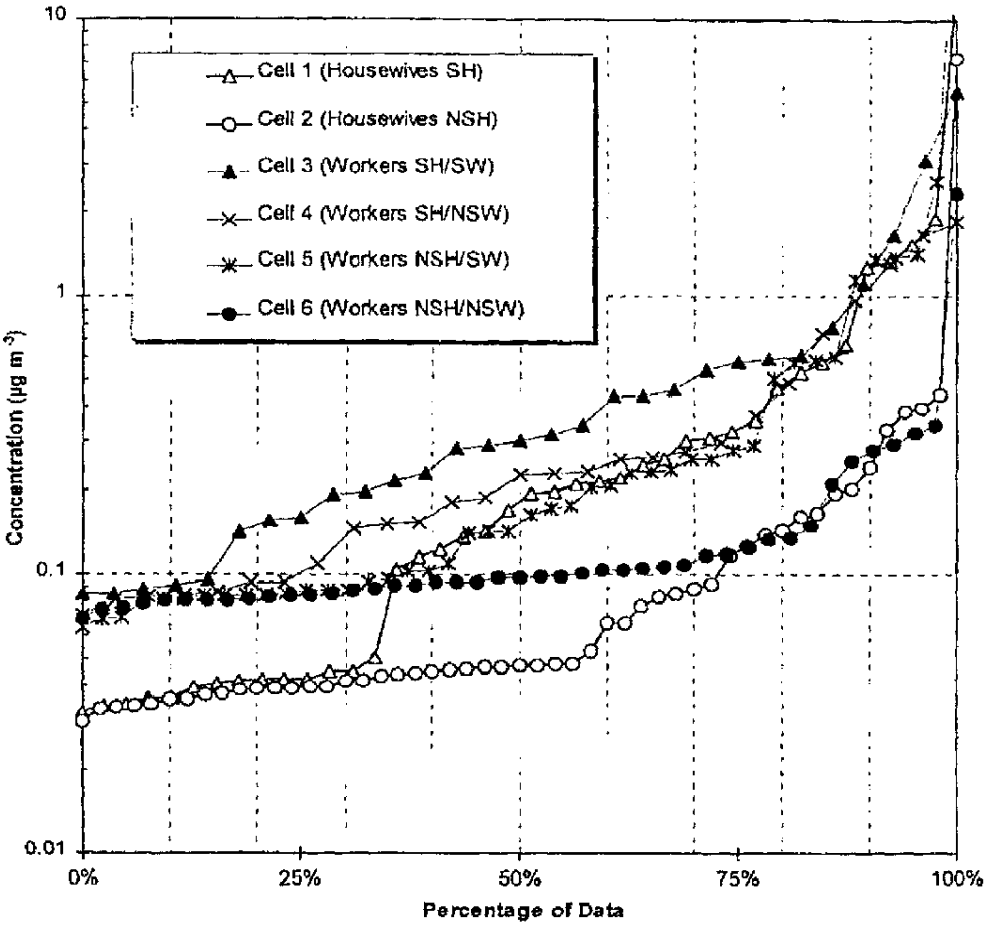

FIGURE 3. Cumulative frequency distributions of 24-h TWA particulate matter concentrations found in Kuala Lumpur by cell. SH: smoking household, NSH: nonsmoking household, SW: smoking workplace, NSW: nonsmoking workplace.

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Source: https://www.industrydocuments.ucsf.edu/docs/gshj0001

TABLE 7. Cotinine and 24-h TWA Nicotine and 3-EP Concentrations for all Subjects by Cell

Analyte	Subject group	Number of subjects	10th percentile	90th percentile	Arithmetic mean	Geometric mean	*Median*
	Cell 1	40	0.04	1.3	0.65	0.17	***0.18***
	Cell 2	51	0.04	0.24	0.24	0.08	***0.05***
Nicotine	Cell 3	29	0.09	1.2	0.66	0.34	***0.30***
($\mu g\ m^{-3}$)	Cell 4	27	0.08	1.1	0.40	0.24	***0.23***
	Cell 5	44	0.08	1.3	1.1	0.22	***0.15***
	Cell 6	43	0.08	0.27	0.17	0.12	***0.10***
	Cell 1	40	0.03	0.25	0.16	0.06	***0.04***
	Cell 2	51	0.03	0.07	0.07	0.05	***0.04***
3-EP	Cell 3	29	0.09	0.62	0.28	0.20	***0.18***
($\mu g\ m^{-3}$)	Cell 4	27	0.08	0.47	0.21	0.16	***0.11***
	Cell 5	44	0.08	0.38	0.20	0.15	***0.12***
	Cell 6	43	0.08	0.20	0.14	0.11	***0.10***
	Cell 1	42	0.50	2.0	1.0	0.80	***0.50***
	Cell 2	50	0.50	1.2	0.79	0.64	***0.50***
Cotinine*	Cell 3	29	0.50	1.8	1.1	0.88	***0.85***
($ng\ mL^{-1}$)	Cell 4	29	0.50	2.1	1.2	0.95	***1.1***
	Cell 5	45	0.50	1.2	2.3	0.72	***0.50***
	Cell 6	44	0.50	0.78	0.65	0.58	***0.50***

Cell 1 : smoking household
Cell 2 : nonsmoking household
Cell 3 : smoking household / smoking workplace
Cell 4 : smoking household / nonsmoking workplace
Cell 5 : nonsmoking household / smoking workplace
Cell 6 : nonsmoking household / nonsmoking workplace

3-EP = 3-ethenylpyridine

* Values calculated from the average of pre- and post-monitoring saliva cotinine concentrations.

Time weighted average (TWA) exposure concentrations, determined for each subject from measured levels both inside and outside the workplace, were used to calculate the above vapour phase statistical parameters for Cells 3 to 6.

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Source: https://www.industrydocuments.ucsf.edu/docs/gshj0001

Potential Inhaled Quantities of RSP, ETS Particles and Nicotine

The term "exposure" is often used when defining maximum allowable concentrations for hazardous compounds, and is normally determined by fixed site monitoring over standard time periods. In the context of this personal monitoring study, where concentrations cannot be directly related to a specific environment, the term "potential inhaled quantity (PIQ)" has been used as a measure of total exposure. PIQ was calculated as the product of the analyte concentration, the length of time subjected to such concentration and the breathing rate maintained throughout the period. A similar assumption was recently made by Ogden and Martin (1997) who noted that this provided "a more accurate accounting of total exposure among individuals as they engage in different activities in different microenvironments". Where PIQs have been quoted in terms of cigarette equivalents (CEs), these have been calculated in relation to the mainstream particle (tar) and nicotine yields of typical Malaysian cigarettes, although it is recognized that the particle phases of ETS and mainstream smoke differ considerably in composition and particle size. The values, 20 mg mainstream particles (tar) and 1.5 mg nicotine, were calculated as the mean of the yields of the top six selling cigarette brand-types in Malaysia. In this publication calculated CE values are used solely for conceptual comparison of exposures between groups of nonsmokers. In this context the factor used to relate ETS exposures of nonsmokers to smokers (Ogden and Martin, 1997) was not required.

Daily exposures, in terms of PIQs, calculated for each subject group (Cell) over the 24 h monitoring periods, are summarized in Table 8. The daily PIQ for each subject was calculated using the subjects breathing rate together with the concentrations and sampling times determined from their individual monitors. As in previous studies by these authors, an "awake" breathing rate of 0.65 $m^3 h^{-1}$ for females and 1.05 $m^3 h^{-1}$ for males (Holcomb, 1993) was assumed at all times. Median and 90th percentile PIQs were subsequently calculated for each Cell from these individually calculated daily values in order to represent "typical" and "highly exposed" subjects respectively. RSP, nicotine and ETS particle exposures during the monitoring period were also calculated using similar procedures according to subject gender and are reported in Table 9. Based upon median PIQs, and irrespective of gender, office workers in this study were exposed to at least four times the daily amount of ETS particles (SolPM) and at least double the daily amount of nicotine than nonworking subjects.

In order to estimate annual exposure, separate procedures were adopted for housewives and for workers. Annual PIQs for each housewife were calculated by assuming they were exposed to their measured concentrations for an entire year and that a breathing rate of 0.65 $m^3 h^{-1}$ was maintained at all times. For workers in Cells 3 to 6, annual PIQs were calculated for each subject from the data provided by the separate monitors worn in the workplace and away from the workplace. Male and female working subjects were assumed to have breathing rates of 1.05 $m^3 h^{-1}$ and 0.65$m^3 h^{-1}$ respectively at all times and to spend 35-h per week and 48 weeks per year in the workplace. Calculation of annual PIQs for all subjects assumed no variation in ETS marker concentrations throughout the year, including weekends, from those measured during the monitoring period. Median and 90th percentile PIQs by Cell, calculated from the estimated annual PIQs using the above assumptions, are reported in Table 10 together with estimates for ETS and nicotine exposure in terms of CE.

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Source: https://www.industrydocuments.ucsf.edu/docs/gshj0001

TABLE 8. Estimated Potential Inhaled Quantities (PIQ) of RSP, ETS Particles and Nicotine for all Subjects during the 24-h Monitoring Periods

Subject group	RSP (μg)	ETS particles		Nicotine (μg)
		SolPM (μg)	FPM (μg)	
		Median PIQ		
Cell 1	808	2.0	135	2.9
Cell 2	745	2.0	90	0.74
Cell 3	1120	32	140	6.8
Cell 4	917	28	155	3.4
Cell 5	897	6.4	100	2.7
Cell 6	878	6.4	89	2.1
		90th percentile PIQ		
Cell 1	1286	60	534	16
Cell 2	1392	11	447	3.8
Cell 3	1790	163	301	22
Cell 4	1568	133	334	20
Cell 5	1564	61	255	20
Cell 6	1330	46	262	5.2

Cell 1 : smoking household
Cell 2 : nonsmoking household
Cell 3 : smoking household / smoking workplace
Cell 4 : smoking household / nonsmoking workplace
Cell 5 : nonsmoking household / smoking workplace
Cell 6 : nonsmoking household / nonsmoking workplace

NB. A breathing rate of 0.65 $m^3 h^{-1}$ was assumed for females and 1.05 $m^3 h^{-1}$ for males at all times. The exposure time was that recorded on the monitors worn by each subject.

Ranking Cells according to median annual PIQ of ETS particles (SolPM) indicates Cell 3 > Cell 4 > Cell 5 > Cell 1 > Cell 6 > Cell 2. This ranking was very similar to that found by these authors in Hong Kong. Based upon median PIQs of ETS particles (SolPM) and nicotine, no group would potentially inhale more than 1.3 CEs per year (CE/y) and the least exposed, those housewives living in nonsmoking households (Cell 2), would inhale considerably less than 1 CE/y. The most highly exposed (90th percentile PIQs) nonsmokers in this study, workers who lived with smokers, would receive between 1.9 (SolPM) and 4.6 (nicotine) CE/y. Conversely, if they came from nonsmoking households/workplaces they would potentially inhale less than 1 CE/y. Overall, these were the lowest values reported to date by these authors.

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Source: https://www.industrydocuments.ucsf.edu/docs/gshj0001

TABLE 9. Estimated Median Potential Inhaled Quantities of RSP, ETS Particles and Nicotine for Males and Females during the 24-h Monitoring Periods

Subject group *	RSP (μg)	ETS particles		Nicotine (μg)
		SolPM (μg)	FPM (μg)	
Housewives	758	2.0	109	1.0
Female "workers"	697	9.5	83	2.4
Male "workers"	1194	12	151	3.3

* "Housewives" refers to subjects recruited for Cells 1 and 2 (single monitor). "Workers" refers to subjects recruited for Cells 3 to 6 (dual monitor).

NB A breathing rate of 0.65 $m^3 h^{-1}$ was assumed for females and 1.05 $m^3 h^{-1}$ for males. The exposure time was that recorded on the monitors worn by each subject.

In a previous indoor air quality study conducted in air-conditioned offices in Kuala Lumpur (Robertson and Salmon, 1993), measured levels of tobacco smoke components suggested that office smoking was not a significant factor affecting indoor air quality. This same study also concluded that the ambient or outdoor air in Kuala Lumpur had a significant effect on the quality of indoor air.

Concentrations of RSP, ETS Particles, Nicotine and 3EP Based Upon Location

The concentrations of RSP, ETS particles and nicotine to which working subjects were exposed, both inside and outside of the workplace, were assessed using data provided by the individual monitors. Individual monitor contributions were combined to provide an estimate of exposure concentrations in smoking (Table 11) and nonsmoking (Table 12) environments, both inside and outside the workplace. Comparison of saliva cotinine levels was not meaningful using this procedure and these data have been excluded from the tables.

Median RSP levels were equivalent in both the workplace ("work") and outside the workplace ("home") for both smoking and nonsmoking environments. Median levels of ETS particles (SolPM) and nicotine in the workplace were higher than those measured outside the workplace. Median levels outside the workplace were comparable for both smoking and nonsmoking locations, both falling below the LOQ, whereas workplace concentrations were higher in locations where smoking actively took place. The median levels of ETS particles (SolPM) and nicotine (0.71 μg m^{-3} and 0.28 μg m^{-3} respectively) measured for subjects in smoking workplaces were at the very low end of concentrations found by these authors in European cities (SolPM range 0.59–37 μg m^{-3}, nicotine range 0.20–2.4 μg m^{-3}). The median level for nicotine was similar to that reported by Jenkins et al. (1996) for comparable US workplaces (0.28 μg m^{-3}), although corresponding ETS particle levels (SolPM 0.07 μg m^{-3}) were approximately 10 times lower in the US than in Kuala Lumpur.

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Source: https://www.industrydocuments.ucsf.edu/docs/gshj0001

TABLE 10. Estimated Annual Potential Inhaled Quantities (PIQ) of RSP, ETS Particles and Nicotine for all Subjects by Cell

	Annual PIQ (mg)						
		ETS particles			Cigarette equivalents		
Subject group	RSP	SolPM	FPM	Nicotine	SolPM	FPM	Nicotine
			Median PIQ				
Cell 1	299	0.75	49	1.0	0.04	2.5	0.69
Cell 2	271	0.73	33	0.27	0.04	1.6	0.18
Cell 3	418	5.5	68	2.0	0.28	3.4	1.3
Cell 4	347	8.9	54	0.89	0.45	2.7	0.59
Cell 5	326	2.3	38	0.78	0.12	1.9	0.52
Cell 6	333	2.3	37	0.71	0.12	1.8	0.47
All workers *	338	3.0	42	0.88	0.15	2.1	0.59
			90th percentile PIQ				
Cell 1	506	21	215	7.2	1.1	11	4.8
Cell 2	508	3.9	163	1.4	0.20	8.1	0.92
Cell 3	739	63	109	6.8	3.2	5.5	4.6
Cell 4	577	38	125	5.3	1.9	6.3	3.5
Cell 5	614	17	103	5.5	0.87	5.1	3.7
Cell 6	520	11	104	1.4	0.55	5.2	0.95
All workers *	615	25	112	4.9	1.3	5.6	3.3

Cell 1 : smoking household
Cell 2 : nonsmoking household
Cell 3 : smoking household / smoking workplace
Cell 4 : smoking household / nonsmoking workplace
Cell 5 : nonsmoking household / smoking workplace
Cell 6 : nonsmoking household / nonsmoking workplace

* "All workers": Cells 3 to 6 combined

NB Breathing rates of 0.65 $m^3 h^{-1}$ for females and 1.05 $m^3 h^{-1}$ for males were assumed. Annual PIQs for individuals in Cells 1 - 2 were calculated by extrapolation of their calculated air concentrations to one year as follows :-

$$\textit{Individual annual PIQ} = \textit{air concentration} \times (0.65 \text{ or } 1.05) \times 24 \times 365$$

ETS marker concentrations for workers at work and outside the workplace were calculated from the data provided by the "work" and "home" monitors. Annual exposures for individuals in Cells 3 – 6 were calculated as follows assuming a 35-h working week and 48-week working year with the remainder of the time spent outside the workplace :-

$$\textit{Individual annual PIQ} = \begin{matrix} \textit{"work" concentration} \times (0.65 \text{ or } 1.05) \times 35 \times 48 \\ + \\ \textit{"home" concentration} \times (0.65 \text{ or } 1.05) \times ((24 \times 365) - (35 \times 48)) \end{matrix}$$

Median and 90th percentile data were calculated for each cell from the individual PIQs as determined above.

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Source: https://www.industrydocuments.ucsf.edu/docs/gshj0001

TABLE 11. Concentrations of RSP and ETS Markers for Working Subjects in Smoking Environments

Analyte	Environment*	Number of subjects	10th percentile	90th percentile	Arithmetic mean	Geometric mean	*Median*
RSP	Work	73	23	88	52	43	*44*
($\mu g\ m^{-3}$)	Home	59	23	83	53	46	*48*
SolPM	Work	74	0.31	9.4	3.6	1.2	*0.71*
($\mu g\ m^{-3}$)	Home	59	0.20	2.7	2.4	0.52	*0.23*
FPM	Work	73	1.1	11	6.2	3.4	*3.7*
($\mu g\ m^{-3}$)	Home	59	2.2	17	9.5	6.3	*7.2*
UVPM	Work	73	2.5	23	11	7.6	*7.6*
($\mu g\ m^{-3}$)	Home	59	3.4	23	12	8.7	*10*
Nicotine	Work	74	0.10	2.2	1.9	0.37	*0.28*
($\mu g\ m^{-3}$)	Home	59	0.06	0.61	0.28	0.15	*0.09*
3-EP	Work	74	0.10	0.96	0.43	0.25	*0.15*
($\mu g\ m^{-3}$)	Home	59	0.06	0.21	0.13	0.10	*0.08*

* Work - data from "workplace" monitor of subjects in Cells 3 & 5 (mean time 9.1 h)
Home - data from "away from work" monitor of subjects in Cells 3 & 4 (mean time 14.7 h)

Applying the same comparisons to the "away from work" results for subjects from smoking households showed that the median ETS particle level in Kuala Lumpur (0.23 $\mu g\ m^{-3}$, < LOQ) was the lowest found to date by these authors (European range 1.1–21$\mu g\ m^{-3}$, Hong Kong 0.72 $\mu g\ m^{-3}$). The median nicotine level (0.09 $\mu g\ m^{-3}$) was also the lowest found to date (European range 0.15–0.97 $\mu g\ m^{-3}$, Hong Kong 0.31 $\mu g\ m^{-3}$). Jenkins' results from a comparable group (SolPM 1.25 $\mu g\ m^{-3}$, nicotine 0.79 $\mu g\ m^{-3}$) suggests much higher ETS levels in smoking households in the US than those found in Kuala Lumpur.

Subjective Comparisons of ETS Exposure

As part of the last visit survey, study participants were asked a number of subjective questions regarding their exposure to ETS, both in general and during the 24-h monitoring periods. The environments assessed by subjects as being the single location where they are most exposed to ETS are depicted in Figure 4. This chart shows that the majority of recruited subjects believed that they were most exposed whilst outdoors. The same observation was apparent in Hong Kong, but was somewhat different to the findings from the European cities where outdoor locations were not perceived as a major source of ETS. It is possible that lower indoor ETS exposures resulting from good ventilation systems and different attitudes to smoking in Kuala Lumpur may account for this difference in perception. The low analytical results from the personal exposure study, in which the majority of the time was spent indoors, may also support these subjective observations. The indoor location generally perceived to contribute most to ETS exposure was a restaurant or bar area, the same observation to that found in all other cities.

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Source: https://www.industrydocuments.ucsf.edu/docs/gshj0001

TABLE 12. Concentrations of RSP and ETS Markers for Working Subjects in Nonsmoking Environments

Analyte	Environment*	Number of subjects	10th percentile	90th percentile	Arithmetic mean	Geometric mean	*Median*
RSP	Work	72	21	92	48	42	*43*
($\mu g\ m^{-3}$)	Home	88	21	87	59	45	*42*
SolPM	Work	72	0.29	6.0	3.1	0.91	*0.40*
($\mu g\ m^{-3}$)	Home	88	0.19	0.69	1.1	0.30	*0.21*
FPM	Work	72	0.80	15	6.3	2.9	*2.6*
($\mu g\ m^{-3}$)	Home	87	1.4	15	10	4.7	*5.0*
UVPM	Work	72	2.6	23	11	7.1	*6.4*
($\mu g\ m^{-3}$)	Home	88	2.3	24	15	7.6	*6.8*
Nicotine	Work	71	0.09	0.54	0.37	0.20	*0.15*
($\mu g\ m^{-3}$)	Home	87	0.06	0.24	0.22	0.10	*0.07*
3-EP	Work	71	0.09	0.50	0.25	0.18	*0.15*
($\mu g\ m^{-3}$)	Home	87	0.06	0.19	0.13	0.09	*0.07*

* Work - data from "workplace" monitor of subjects in Cells 4 & 6 (mean time 9.1 h)
Home - data from "away from work" monitor of subjects in Cells 5 & 6 (mean time 14.7 h)

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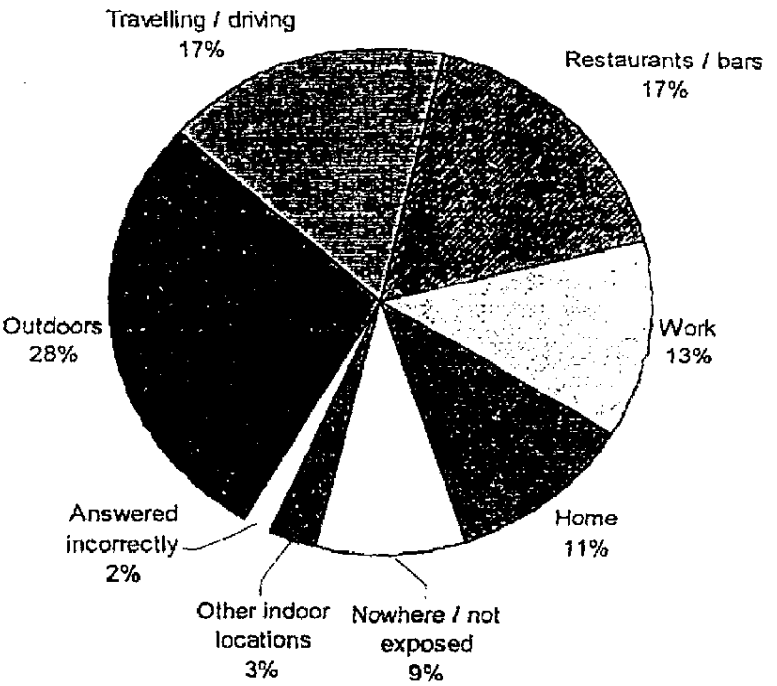

FIGURE 4. Subjective responses to question "In which environment do you think that you are exposed to the most tobacco smoke in the air?" NB subjects were requested to select a single environment, responses plotted below as a percentage of the total recruits, 4 subjects failed to answer this question correctly.

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